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SPONTANEOUS AND INDUCED COHERENT RADIATION GENERATED IN ATOMIC VAPOR

FINAL REPORT

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Optical coherent techniques have been developed and applied in order to obtain relaxation and spectroscopic information in atomic vapors. Theoretical work was performed to understand collisional relaxation and the interaction of intense fields with matter. The utility of using incoherent light fields in generating coherent excitations was demonstrated and analyzed. Applications of the time delayed four wave mixing technique using broadband light for investigating relaxation in solids have begun.

SUMMARY OF WORK SUPPORTED BY ONR 1978 - 1988
(CONTRACT # N00014-78-C-0517)

SPONTANEOUS AND INDUCED COHERENT RADIATION GENERATED IN ATOMIC VAPOR

by Sven R. Hartmann, Professor of Physics
Columbia University in the City of New York

We have developed and applied various optical coherent techniques in order to study relaxation processes in gases as well as to obtain a better understanding of the interaction between light and matter.

Using the tri-level technique we were able to study the collisionally induced relaxation of Rydberg states in Na vapor to principal quantum numbers, n, as high as 40. These measurements were able to follow the relaxation behavior over the low n regime where the collision cross section increased with increasing n as well as the high n regime where the opposite occurs.[1,7,9,10,34,38] The related Raman Echo was used to study collision broadening of the $6P_{1/2}$-$6P_{3/2}$ transition in Tl vapor.[17,20] Another related phenomena is the two-photon excited state tri-level echo.[31,33,37] This echo, of interest in its own right, is useful for studying superposition state relaxation of states unaccessible by ordinary photon echo techniques.

We were able to induce spatial gratings to reform. These novel echoes have signatures relevant to spectroscopic and velocity changing collisions studies.[2,5]

Stimulated echoes were used to study general collisional relaxation effects in gases.[3,4,]

Two-pulse photon echoes were used to provide the first demonstration of the contribution of velocity-changing-like effects to the transverse relaxation of atoms in superposition of two states even when the states follow different post-collision trajectories.[6] Related works allowed us to study foreign gas broadening of the Na and Li D lines.[8,13,16,21] The potential of the two-pulse photon echo technique for performing high resolution spectroscopy was demonstrated in an experiment which showed that echoes could be obtained over a dynamic range exceeding 10^{12}.[27]

An extensive theoretical analysis was made of the properties of collision kernels in atomic physics problems.[19]

A diagrammatic technique was developed to aid in the analysis of pulse type optical coherent experiments.[11] This technique was further developed into the practical Billiard Ball Model[24,26] which has provided a simple pictorial method of analyzing generalized echo experiments.[15,18] The elliptical Billiard Ball Model stimulated experiments which gave added insights into echo behavior and confirmed its validity.[22,23,25,27,28]

A theorem stating that optical coherent transients from an excited optically thin sample can produce coherent radiation signals for a time no longer than the length of the total excitation pulse had been proposed, and we pointed out that it was not correct.[14]

We considered and commented upon the spectral modification and temporal modification of a narrow-band light pulse propagating through an atomic absorber that has a still narrower spectral hole.[12]

Another experiment of generalized interest involved the properties of "Diffraction Free Beams." We demonstrated novel properties of these beams involving their inability to be blocked.[40]

We demonstrated that it is possible to generate photon echoes with incoherent light.[29] Before this experiment it was widely held that coherent light was necessary to generate echoes. It turns out that the incoherent echoes generated in this way can be much larger than the echoes generated with coherent light.[39] This experiment led to investigations involving time delayed mixing with incoherent light.[30,32] These experiments in turn showed us there was a need for a theoretical analysis which went beyond perturbation theory. We developed such a theory[41] and are now applying it in order to understand problems associated with the interaction of noisy light and matter.

Our increased understanding of the interaction of light and matter led us to use coherent lasers in conjunction with time delayed four wave mixing, which in turn enabled us to develop a new technique which we called Ultrafast Modulation Spectroscopy.[35,36] This technique involved a time delayed four wave mixing experiment using coherent lasers configured to produce picosecond beats in Na vapor. This technique is Doppler free. A more recent advance involves a variant of this technique which produces attosecond beats.[42]

We have begun to use the time delayed four wave mixing technique to study relaxation in glasses doped with CdS and CdSe. We have been able to observe relaxation processes in the tens of femtosecond regime. The technique is promising. The time resolution only depends on the bandwidth of the laser noise. We are also setting up to look at ultrafast relaxation processes in GaAs quantum wells.

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